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[From the Proceedings of the American Association for the Advancement of Science,
Detroit Meeting, August, 1875.]

12
**THE EFFECT OF THE GLACIAL EPOCH UPON THE DISTRIBUTION OF
INSECTS IN NORTH AMERICA. By AUG. R. GROTE, of Buffalo,
N. Y.**

FROM the condition of an hypothesis, the Glacial epoch has been elevated into that of a theory, by the explanations it has afforded to a certain class of geological phenomena. The present paper endeavors to show that certain zoological facts are consistent with the presence in past times of a vast progressive field of ice gradually extending over large portions of the North American Continent and moving from the north to the south. These facts are in the present instance afforded by a study of the Lepidoptera, certain kinds of butterflies and moths now inhabiting the United States and adjacent territories. Before proceeding with the subject, a brief statement of some of the phenomena assumed to have attended the advent of the Glacial Epoch is necessary.

At the close of the Tertiary, the temperature of the earth's surface underwent a gradual change by a continuous loss of heat. The winters gradually became longer, the summers shorter. The tops of granitic mountains in the east and west of the North American continent, now in summer time bare of snow and harboring a scanty flora and fauna, became, summer and winter, covered with congealed deposits. In time the mountain snows consolidated into glacial ice which flowed down the ravines into

the valleys. Meanwhile the northern regions of the continent, which may have inaugurated, submitted extendedly to the same phenomena. Glacial ice, first made on elevations, finally formed at, and poured over lower levels. Glacial streams finally united to form an icy sea whose frozen waters slowly plowed the surface of the rocks; and whose waves, in their movement from north to south, absorbed the local glaciers in their course, and extended over all physical barriers into the Southern States and down the Valley of the Mississippi. To the main Ice-sheet, the Appalachians and Rocky Mountains are supposed to have contributed their local glaciers. Before this frozen deluge the animals must have always retreated. The existing insects of the pliocene must, in submitting to the change of climate which accompanied the advance of the glacier, have quitted their haunts with reluctance, and undergone a severe struggle for existence, no matter how gradually they had been prepared for the encounter. We must expect that multitudes of specific forms ultimately perished of whose remains no traces have been preserved.

Such being a brief statement of the outlines of the opening of the Glacial Epoch, we turn to some facts offered by a study of our existing species of butterflies and moths. The tops of the White Mountains and the ranges of mountain elevations in Colorado, offer us particular kinds of these insects living in an isolated manner at the present day and confined to their respective localities. In order to find insects like them we have to explore the plains of Labrador and the northern portion of the North American Continent, in regions offering analogous conditions to those obtaining on the summits of these mountains. The genera *Oeneis* and *Brenthis* among the butterflies, and *Anarta* and *Agrotis* among the moths, are represented by the same or similar species in all of the above mentioned localities. In the case of the White Mountain Butterfly, *Oeneis semidea*, we have a form sustaining itself on a very limited alpine area on the top of Mount Washington.¹ Although there is some doubt that precisely

¹ See Mr. Scudder's article in the "Geology of New Hampshire," 1,342. Mr. Scudder first pointed out the existence of alpine and subalpine faunal belts on Mount Washington, and interestingly remarks "that if the summit of Mt. Washington were somewhat less than two thousand feet higher it would reach the limit of perpetual snow." Consult also, an earlier paper of great value by Dr. A. S. Packard, Jr., on "The Insect Fauna of the Summit of Mount Washington as compared with that of Labrador" (these Proceedings, Vol. XVI, 154). Dr. Packard, in comparing the climate of the two localities, says: "The seasons correspond very exactly, as the snow melts in the early summer, and ice is formed early in the autumn at about the same dates."

QL469

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the same form has been discovered in Colorado, the fact remains that butterflies exceedingly like it, though registered by us under different specific names, live in Labrador and Colorado.

Whether the White Mountain Butterfly be, as suspected by Lederer, a local modification of some one of the Labradorian forms or not, the geographical distribution which its genus enjoys cannot be meaningless. The question comes up, with regard to the White Mountain Butterfly, as to the manner in which this species of *Oeneis* attained its present restricted geographical area. How did the White Mountain Butterfly get up the White Mountains? And it is this question that I am disposed to answer by the action attendant on the decline of the Glacial Epoch.

I have before briefly outlined the phenomena attendant on the advance of the Ice-sheet, and I now dwell for a moment on those which must equally be presumed to have accompanied its retirement. Many of the features of its advance were repeated in reverse order on the subsidence of the main Ice-sheet or Glacial sea. The local glaciers appeared again separate from the main body and filled the valleys and mountains and ravines, running thus at variance with the main body of the Glacier, being determined by local topography. A reversal of the temperature shortened the winters and lengthened the summers. Ice-loving kinds of insects, such as our White Mountain Butterfly, hung on the outskirts of the main Ice-sheet, where they found their fitting conditions of temperature and food. The main Ice-sheet had pushed them insensibly before it, and, during the continuance of the Glacial Epoch, the geographical distribution of the genus *Oeneis* had been changed from a high northern region to one which may well have included portions of the Southern States. And, on its decline, the Ice-sheet drew them back again after itself by easy stages; yet not all of them. Some of these butterflies strayed by the way, delayed by the physical nature of the country and destined to plant colonies forever separate from their companions. When the main Ice-sheet left the foot of the White Mountains, on its long march back to the pole where it now seems to rest, some of these wayward, flitting, *Oeneis* butterflies were left behind. These had strayed up behind the local glaciers on Mount Washington, and so became separate from the main body of their companions which journeyed northward, following the retirement of the main Ice-sheet. They found in elevation their

congenial food and climate, and they have followed these gradually to the top of the mountain, which they have now attained and from which they cannot now retreat. Far off in Labrador, the descendants of their ancestral companions fly over wide stretches of country, while they appear to be in prison on the top of a mountain.

I conceive that in this way the mountains generally may have secured their Alpine animals. The Glacial Epoch cannot be said to have expired. It exists even now for high levels above the sea while the Laplander and Esquimaux find it yet enduring in the far North. Our yearly winters are fractions of the Glacial year. Had other conditions been favorable, we might now find Arctic man living on snow-capped mountains in the Temperate zones.

At a height of between 5,600 and 6,200 feet above the sea and at a mean temperature of about forty-eight degrees during a short summer, the White Mountain Butterflies (*Oeneis semidea*), yet enjoy a climate like that of Labrador within the geographical limits of New Hampshire. And in the cases of the moths² an analogous state of things exists. The species *Anarta melanopa* is found on Mount Washington, the Rocky Mountains and Labrador. *Agrotis islandica* is found in Iceland, Labrador, the White Mountains, and, perhaps, Colorado.³ As on islands in the air, these insects have been left by the retiring of the ice-flood during the opening of the Quaternary.

On inferior elevations, as on Mount Katahdin in Maine, where we now find no *Oeneis* butterflies, these may have formerly existed, succumbing at last to a climate gradually increasing in warmth from which they had no escape; while the original colonization in the several instances must have always greatly depended upon local topography.

In conclusion, I have briefly endeavored to show that the present distribution of certain North American insects may have been brought about by the phenomena attendant on the Glacial Epoch. The discussion of matters connected with this theoretic period of the earth's history, still, as it now appears, brings out more and more a clearer conception of its actuality. I hope that

² I have since (*Psyche*, I, 131) recorded the first indication of the occurrence of the Arctic *Larva Rossii* on Mount Washington, from a single specimen taken by Mr. B. Pickman Mann, above the tree line.

³ I believe Dr. Packard's identification of this species, in Prof. Hayden's Reports, is incorrect. The Coloradian species is *Agrotis ausiliaris*, Grote.

my present statements may draw the attention of our zoölogists more fully to the matter, seeing that we have in our own country fields for its full exploration. And I permit myself to believe, that testimony as to the former existence of a long and widely spread winter of the years, is offered in evidence through the frail, brown, *Oeneis* butterflies, that live on the tops of the mountains.

[Printed at the SALEM PRESS, June, 1876.]



